NISTIR 6320

Internet Commerce for Manufacturing Product Data

Curtis Parks
ICM Project

April 14, 1999

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of Standards
and Technology
Electronics and Electrical Engineering Laboratory
Electricity Division
Gaithersburg, MD 20899

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Internet Commerce for Manufacturing Product Data

by Curtis Parks

Abstract

Printed circuit assemblies (PCA) typically are designed on computer aided design (CAD) systems, checked, then released for manufacture. The released design description typically consists of a top assembly drawing and a series of data files which are used in various stages of manufacture. The Internet Commerce for Manufacturing Project proposed the development of a system to deliver design data in a form that could be viewed over the Internet. This paper describes the user interface developed for an Internet delivery system. Two ways to present a design using electronic hypertext media are described. The second set of electronic product data packages were validated for completeness and utility in the process of an actual procurement.

1.0 Introduction

A project was initiated to respond to an industry need to utilize the Internet to improve the supply chain effectiveness for the printed circuit assembly (PCA) product. Named the "Internet Commerce for Manufacturing," this project became a member of the National Advanced Manufacturing Technology (NAMT) in mid 1998 [Reference: http://www.mel.nist.gov/namt/projects/icm/icm1.htm]. The ICM project proposed a testbed for development and integration of applications and software related to the PCA supply chain. The project recognized two areas which must function together; the electronic commerce for transacting the business functions, and the product data to be communicated between the original equipment manufacturer and the contracted fabrication and assembly service provider(s).

The product data aspect of the ICM Project would require Internet methods for both the "presentation" of the data, and a "representation" of the data. Presentation (i.e., user interface) is distinguished apart from representation to explore the methods for making the design data *visible* as World Wide Web ("Web") information; independent of the delivery formatting of the data. Addressing the presentation aspect of the problem was felt to be a means to identify development needed in the remaining parts of the PCA delivery system. The data presentation would require analysis of the current practice for revealing PCA designs within the supply chain, determining the problems in the current methods, and exploring the enabling Internet techniques.

2.0 Scenario Workshop Lessons Learned

The ICM Project visited two circuit board assembly facilities and a bare board fabrication business. In addition, IPC, Inc., an organization representing the industry and which leads the development of standards for circuit boards, provided a view of present industry practices. The presenters highlighted supply chain inefficiencies such as, "our industry virtually never receives design data which are sufficient to build the product without requests for added data or clarifications." In addition they noted that there was a need to view the product top assembly and Bill of Materials (BOM) in the "front office" where a CAD system is not available.

To learn about industry's other experiences with using Web pages as a replacement for a drawing, a request for information was sent to a standards project e-mail distribution list. Several replies were received indicating that raster images and Postscript has been used for drawings, and Hypertext Markup Language (HTML) or plain text had been used over the Internet for the BOM and drawing "notes." These responses also indicated that there did not seem to be either a definitive or a frequent use of these techniques.

3.0 Completeness of the Design Data

Three principal sources provided the definition of "sufficient" information for PCA product manufacture:

1. the Web page "job submit" forms used by several board manufacturing companies,
2. the descriptions of output capability from a CAD system, and
3. the lessons learned from the first ICM Website constructed for the analysis and procurement of a PCA design.

These sources indicate that for the separate stages of circuit board procurement and fabrication, the following information is essential:

3.1 Data Required for Manufacturing Analysis

An ICM partner organization, ADI, Inc. (a division of Automata, Inc.), supplies a manufacturability analysis software package and also runs analysis on contract basis. The analysis software performs the analysis by mapping the photo plotting file data from a design— building a pixel-based mapping of the conductive geometry—then compares the geometry to the connection netlist supplied from the engineering schematic for the design. These photoplot Gerber files are typically supplied to the board shop to create the photo artwork tooling for each layer of the board. The files may have been extracted from either the design system's internal database, or from a transfer format. By using these tooling files, errors in data exchange and transfer as well as layout errors will be detected by the analysis process.

The netlist used in the analysis must be in "pin-priority" form. That is, each component pin is listed, together with the name of the signal expected to be at that pin, and the 2-dimensional coordinates for the pin. The commonly accepted format for this file is specified in the IPC-D-356 standard. As an alternative to the netlist, a filter is available to extract the needed information from the complete CAD ASCII file.

Both the netlist and the Bill of Material list uniquely identify each component on the board with a reference designator. The industry follows the reference designator assignment specified in ANSI Y32.16-1975 (R1 for resistor #1, U1 for integrated circuit 1, etc.).

3.2 Data Required to Manufacture the Board

The boards are fabricated from one or more "details." Each detail is composed of a sheet of insulating material (commonly FR4 fiberglass) which has a copper sheet laminated to each side. Each detail requires two Gerber phototool files; one for each side.

If holes or vias are required which only pass through the one detail, then a detail drill schedule and drill list is required. When the board is composed of more than two conductive layers, then the required number of details are stacked; insulating them from each other by intermediate insulating material (commonly called B-stage).

The stacking of the details requires tooling alignment targets called "fiducials." The fiducial coordinates may be supplied as a separate file or may be developed from "target" patterns in the Gerber data files.

The composite board requires a drill schedule and drill list file for the holes and vias which pass through the board. Rarely, holes are required which only penetrate partially through the board. These holes require a separate drill schedule and list.

The board will usually be coated with a solder mask and silk screen (labeling and text). These special layers also employ separate Gerber photo tool files. The particular kind of solder masks and the silk screen ink color are specified as drawing notes.

Finally, the finished dimensions are specified either as dimensions or as notes on a drawing. A router will be used to trim excess material to the dimensions specified.

Board supply contracts can require board continuity testing. The netlist file described under 2.1 may be used for this purpose. A "DITMCO" tester-specific file may also be used.

3.3 Data Required to Complete the Board Assembly

A variety of machines are used to apply adhesive and to place the parts on the board. These machines each require information in particular component sort order. Only those parts which are to be placed by the specific machine are listed in the machine's placement or insertion file. These files are exported from CAD systems as requested, or may be derived from neutral exchange files.

Both in-circuit test and final functional tests are often specified. Files for contracted testing are exported from the CAD system. Functional test files may also be exported by the circuit simulation system data developed during design analysis.

Conformal coating may be applied to the assembly, and special packing may be required. These operations are indicated as drawing notes or as text on the contract.

4.0 Information Delivery methods

In the delivery method employing the least electronic data transfer, all information is in the form of paper drawings. More recently, delivery of the file has been through a "Contractor's Technical Data Package"; a collection of data made available at the contractor's computer facility. The files needed for bare board fabrication are typically included in a file archive set which is compressed and delivered as one file. The file is identified on the contract and on the Bill of Material for the board assembly drawing.

Some or all of the data has also been sent by Internet or mailed on disk, however the Bill of Material and the top assembly drawing were found to be commonly supplied on paper which is sent or hand delivered.

During the ICM Scenario Workshops, the top assembly drawing has been cited as particularly problematic. For purposes of developing process planning and tooling, the shop can seldom complete the product without a graphic layout of the components on the board. The layout must include the annotation of the reference designator of each component. A full assembly drawing is preferred, including the notes mentioned in 2.2 above. Usually a silk screen has been developed for the board which is sufficient for the component layout information. The notes and bill of materials may then be delivered separately as text files.

5.0 Presentations Developed for the ICM Product Data

Two Web presentations of PCA product data have been developed as of this paper, although there may need to be further research in this area. Both of these presentations used a HTML page to list and link the manufacturing files in a file directory. The differences were in the method of presenting the drawing or layout graphics information.

5.1 The Initial Product Data Strawman

Appendix A is a print of the initial product data strawman. A board designed by the Electronic Instrumentation Metrology Group of the Electricity Division was selected. The design was displayed on the CAD system, and captured as a screen bitmap file. The bitmap file was converted to a GIF (graphic interchange format) raster image file.

The Bill of Materials was exported from the system as a text file. HTML anchors were added to the text list, and a client-side image map was developed for the GIF file. The bare

board files were collected in a sub directory and listed and linked in a separate HTML page.

The key feature of the page was that a person viewing the board image could note the reference designator of the part which was under the cursor arrow—both as a visual marking on the image, and as the indication of the anchor in the browser. A click on any component on the board image caused the display to jump to the corresponding entry in the Bill of Material.

Many component manufacturers list their products in on-line Web catalogs. With the Bill of Material in a Web environment, the use of links to the manufacturers catalog listing for some of the parts was incorporated and demonstrated. The use of a link to catalog listings employing an evolving standard for XML (eXtensible Markup Language) was also demonstrated.

The resulting files were reviewed by the ICM followed by a presentation to one of the collaborating assembly shops. The client-side image map was felt to be of greatest benefit to the shop people who needed to identify the part number and location of a failed or missplaced component.

5.2 The Follow-on Product Data Presentation

Through collaboration with the NIST Manufacturing Enterprise Programs (MEP), arrangements were made to procure two circuit boards which had been designed and were needed for research within the Electronic Instrumentation Metrology Group. The data for these boards as posted are shown in Appendix B. As in the previous presentation, a bitmap CAD image was converted to a GIF image. In lieu of an image map, an assembly drawing printer file was output from the CAD system. This file was converted to PDF (Portable Document File) format and linked from the assembly's HTML page.

The board files (each board in a separate directory) were linked from a Request for Quote Web page. Collaborating shops and additional companies in the circuit board business were asked to bid to the product description as posted.

As a collaborator, ADI, Inc. ran their manufacturability analysis on the posted board data. An error was detected on one of the boards, and e-mail sent to the project and the designer. The error was confirmed and the CAD files repaired. The repair information was used to create an Engineering Change Order (ECO) as a Web page as shown in Appendix C. The product revision was assigned a change letter, and all revised files were re-posted.

Several companies bid on the bare board fabrication. A winning bidder was selected and a purchase order was issued. The boards are to be hand assembled, however the Manufacturing Research Center of Georgia Tech will test the effectivity of the assembly data provided in their production floor environment.

These board pages were also reviewed by the ICM participants and collaborators. The PDF files were felt to be useful to people who were involved with the assembly planning

and test. The use of vector graphic images allows for enlarging specific areas or "zooming in" while retaining image resolution. With vector graphics, plots may also be made to any desired scale for use as shop aids.

6.0 Conclusions

The presentation concepts were demonstrated to be a particularly effective method for delivery of "just in time" product data within the PCA supply chain.

Comments received from both reviewers and bidders indicate that the printed board presentations were more effective than general industry practice in delivering the product data to both shop floor and administrative people. The board in particular is usually identified as a new or a revised design for each purchase order or production run (i.e., a board typically has a short production lifespan). Hypertext is effective in accommodating the industry practice of listing the board itself as an item in the BOM of the printed circuit assembly.

Notes which normally are an integral part of a paper drawing of a printed board are effectively communicated as Web text. Many of these notes cannot be automatically derived from the CAD data. In particular, the following notes text has been identified as typically appearing on the board's drawing:

- Material type
- Board maximum thickness
- Board maximum width
- Board maximum height
- Layer count
- Copper weight
- Finish plating
- Solder mask type
- Trace minimum width
- Trace minimum spacing
- Pad pitch minimum
- Smallest hole diameter
- Connector finger finish
- Silk screen color / top
- Silk screen color / bottom

Research on the approaches to presenting the drawing as graphics can be revisited when more advanced Web vector graphics are incorporated into Web browsers. A new standard to use XML format to transmit a bill of material is now being developed. The new standard is expected to become part of the IPC standard suite for printed circuit assembly data.

Appendix A

The following pages have been printed from a Web browser.

PCA Assembly Viewer Strawman; 7 pages [Reference: http://www-i.nist.gov/icm/BoardPage/AssyView.htm, 25 February 1998.]

> This HTML page contains the top assembly image of the circuit board together with the Bill of Materials and a links to the related Printed Board page.

Printed Board; 1 page [Reference: http://www-i.nist.gov/icm/BoardPage/BrdView.htm, 7 May 1998.]

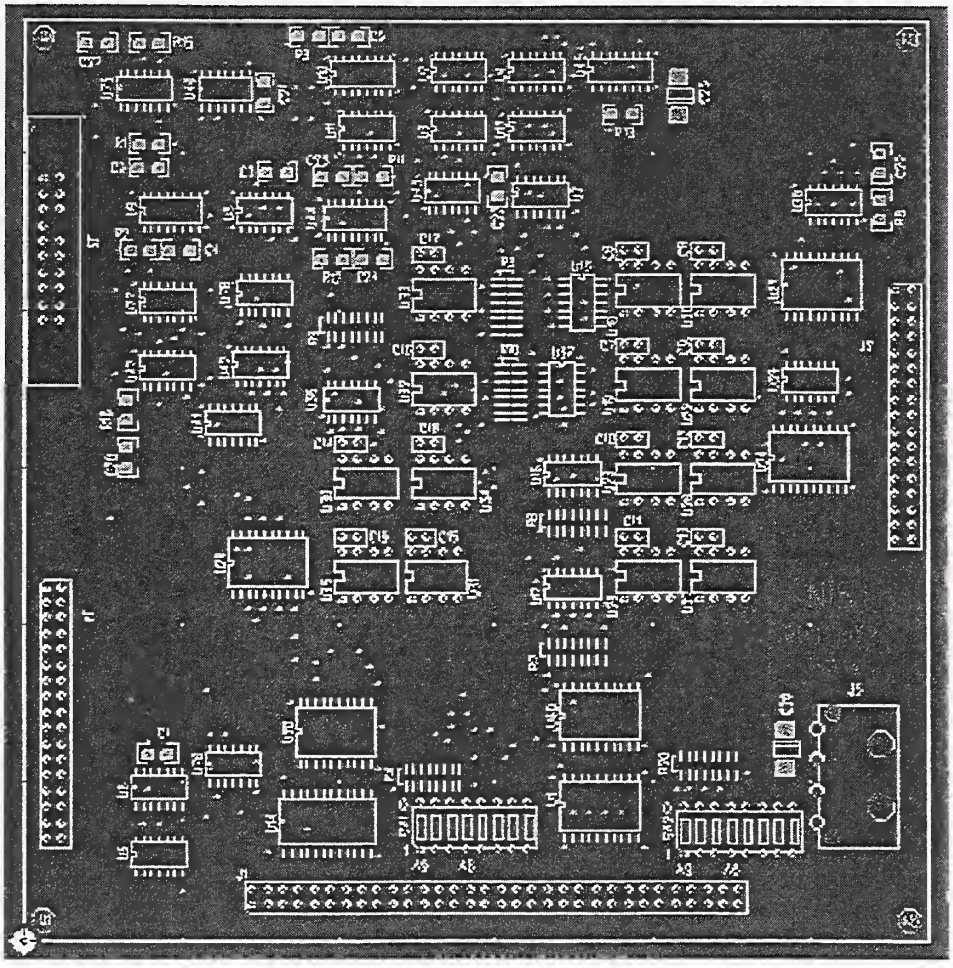
> This HTML page contains the "notes" related to the printed board together with a table of the board's layers. Each layer contains a link to an image page and to the files of the layer's photo tool file.

Internet Commerce for Manufacturing

PCA Assembly Viewer Strawman

This page has been developed as part of the Internet Commerce for Manufacturing program at NIST to explore possible tools for companies involved in the assembly of printed circuits. This page identifies the location of each component in the Bill of Materials (BoM).

Each of the components in the assembly view below is hypertext-linked (described at end of page) to the entry in the BoM that follows the image:



Part Number: RMS_INT2
Revision: A
Job Number: 00001
Invoice Number: 1xxx1998
(link needed here to our Approved Vendor List)
Technical Contact; PCA Designer: Robert H. Palm Jr., (301) 975-2441
The schematic-derived netlist; supplied for testing
Units: X & Y values are in millimeters

Bill of Material

Printed Board Finish size: 146 x 149

Board components as follows
NOTE: Manufacturers of *-marked components provide IGES or DXF model data.

Attribute Order:

Ref	PartNo	Xcent	Ycent	Rotation
C27	CC1206	11.684	145.415	180
R15	CR1206	20.066	145.415	0
M4	MTGHOLE	3.175	146.050	0
U75	74LS14	19.050	137.998	0
U46	74LS32	32.385	137.998	0
C21	CC1206	38.735	137.541	90
U10	74LS221	54.610	140.526	0
U7	74F08	70.485	141.173	0
U4	74F32	83.185	141.173	0
U45	74LS221	96.520	141.161	0
R13	CR1206	96.774	133.985	180
C25	TANT10UF	106.045	137.033	90
U12	74LS32	83.185	131.648	0
U3	74LS14	70.485	131.648	0
U11	74LS74	55.245	131.648	0
R11	CR1206	56.261	123.825	0
C23	CC1206	49.784	123.825	180
C2	CC1206	40.894	124.460	180
U8	74LS74	38.735	118.313	0

U9	74LS221	23.495	118.301	0
C4	CC1206	25.019	111.760	180
R2	CR1206 1	8.669	111.760	180
J3	HEADER20A*	4.445	111.760	270
U77	74F32	22.860	103.708	0
U78	74F32	38.735	104.978	0
R12	CR1206	49.784	110.490	180
C24	CC1206	56.261	110.490	0
C17	DCAP\SR15	65.405	111.125	180
U33	HPCL-2430	67.945	104.775	0
R5	R7XXXCT	78.296	102.870	0
U15	DM7406M	90.373	103.505	270
U18	HPCL-2430	100.965	105.410	0
U20	HPCL-2430	113.030	105.410	0
C8	DCAP\SR15	110.490	111.760	180
C6	DCAP\SR15	98.425	111.760	180
U2	74F08	83.820	120.853	0
C22	CC1206	76.835	122.174	270
U43	74LS74	69.215	121.488	0

U44	74LS221	53.340	117.031	0
R9	R7XXXCT	53.340	99.886	90
C16	DCAP\SR15	65.405	95.885	180
U32	HPCL-2430	67.945	89.535	0
R10	R7XXXCT	78.931	88.900	0
U37	DM7406M	87.198	89.535	270
U19	HPCL-2430	100.965	90.170	0
U22	HPCL-2430	113.030	90.170	0
U39	DM7407M	127.000	91.008	0
J2	HEADER34*	142.240	85.090	270
U24	74F541	127.000	78.486	0
U26	HPCL-2430	113.030	74.930	0
U23	HPCL-2430	100.965	74.930	0
U16	DM7406M	88.900	75.768	0
R6	R7XXXCT	89.535	68.136	90
C11	DCAP\SR15	98.425	65.405	180
C13	DCAP\SR15	110.490	65.405	180
U27	HPCL-2430	113.030	59.055	0
U25	HPCL-2430	100.965	59.055	0
U17	DM7406M	88.900	57.353	0

```
R7   R7XXXCT       89.535 47.181 90

U40  74F521SC      93.345 36.576 0

U1   74F521SC      93.345 21.971 0

SW1 DIPSWITCH_ISA 73.025 18.415 0

U14  74LS646       48.895 19.431 0

R4   R7XXXCT       66.040 26.861 90

U28  74F541        50.165 34.036 0

U76  74F08         33.655 28.778 0

C1   CC1206        21.336 30.480 0

U6   74LS32        21.590 24.968 0

U5   74LS14        21.590 14.173 0

M1   MTGHOLE        3.175 3.175 0

J1   HEADER64*     76.200 6.985 0

SW2 DIPSWITCH_ISA 115.570 17.780 0

R20  R7XXXCT      110.490 28.766 90

C26  TANTCHIP293 123.190 31.242 270

J5   C-Power      133.350 26.670 270

M2   MTGHOLE      142.875 3.175 0

U31  HPCL-2430     66.675 59.055 0
```

U35	HPCL-2430	55.245	59.055	0
C19	DCAP\SR15	52.705	65.405	180
C15	DCAP\SR15	64.135	65.405	180
U34	HPCL-2430	67.945	74.295	0
U30	HPCL-2430	55.245	74.295	0
C14	DCAP\SR15	52.705	80.645	180
C18	DCAP\SR15	65.405	80.645	180
U36	DM7406M	52.705	87.833	0
U41	74F08	33.655	84.023	0
R16	CR1206	16.510	86.106	90
C28	CC1206	16.510	78.359	270
U47	74LS32	22.860	92.913	0
U42	74LS14	38.100	93.548	0
C7	DCAP\SR15	98.425	96.520	180
C9	DCAP\SR15	110.490	96.520	180
C12	DCAP\SR15	110.490	81.280	180
C10	DCAP\SR15	98.425	81.280	180
U21	74F541	128.905	106.426	0
U38	DM7407M	130.810	119.583	0
R8	CR1206	138.430	118.364	270

```
C20   CC1206      138.430 125.984 270

M3    MTGHOLE     142.875 146.050 0

C5    CC1206       52.324 146.685 180

R3    CR1206       45.974 146.685 180

R1    CR1206       20.066 128.905 0

C3    CC1206       19.939 125.095 180

U29   74F244       39.370 61.341 0

J4    HEADER34*     5.080 36.830 270

U13   74LS374      (ON BOTTOM)

U48   74LS374      (ON BOTTOM)

U49   74LS646      (ON BOTTOM)
```

***** END OF BOM *****

The page presents actual production data.
Several manufacturing files were extracted from a native CAD design file and merged into a BOM text file.
The top assembly graphic is a CAD screen image reformatted as a GIF.
A client-side image map links the components to their BOM entry.

HTML by C. Parks; created 2/25/98
Comments welcome, phone (301) 975-3517 or e-mail to parks@eeel.nist.gov .

Printed Board Technical Data

Assembles into: RMS_INT2, Rev A
Acceptability Standard: IPC-A-600E
Layer Count: 6
Material: FR4, 1 oz copper
Thickness max: .062"
Drill size table
Drill schedule file (no blind or buried holes)
Soldermask: LPI; over bare copper; (no gold plated areas)
Silkscreen: White ink

Layer	Function	CAD Color	Data Files
Top	Silkscreen	Lt Green (Blue=text)	Gerber Apertures Image (GIF)
Top	Soldermask	(generate)	
1	Route (signal)	Lt Blue (vias=teal)	Gerber Apertures Image (GIF)
2	Ana/Dig Gnd	Yellow	Gerber Apertures Image (GIF)
3	+5V	Purple	Gerber Apertures Image (GIF)
4	+5VB	Green	Gerber Apertures Image (GIF)
5	RoutingH	Red	Gerber Apertures Image (GIF)
6	RoutingV	Brown	Gerber Apertures Image (GIF)
Bot	Soldermask	(generate)	
Bot	Silkscreen	Gray	Gerber Apertures Image (GIF)

ICM Project; 5/7/98
Data Files: Robert Palm
HTML: C.H. Parks

Appendix B

The following pages have been printed from a Web browser.

Viewing the Product Data Package; 1 page [Reference: http://www.eeel.nist.gov/~parks/icm/pcafiles, 18 February 1999.]

> This HTML page contains the introductory information and the links to the two separate circuit board pages.

Strobe Control Board; 3 pages [Reference: http://www.eeel.nist.gov/~parks/icm/pcafiles/strb_ctrl, 18 February 1999.]

> This HTML page contains the images of the top and bottom Assembly Views, and links to all related files.
>
> Note that the images have been truncated at the right margin; they are completely visible within a Web browser and are in color as would be viewed in a CAD system screen.

Top Parts Placement View; 1 page [Reference: http://www.eeel.nist.gov/~parks/icm/pcafiles/strb_ctrl/top.pdf, 18 February 1999.]

> This Portable Document File (PDF) page contains the component placement locations for the top side of the Strobe Control board.

Bill of Materials; 5 pages [Reference: http://www.eeel.nist.gov/~parks/icm/pcafiles/strb_ctrl.BOM.html, 18 February 1999.]

> This HTML page contains the Bill of Materials, in table format, for the Strobe Control board.

Viewing the Product Data Package

The ICM project is purchasing two printed circuit boards. These recently designed boards will be used in an assembly for another NIST Electricity Division research project. We have collected the CAD data files for these boards into an Internet-accessible "Product Data Package" (PDP). The Web pages below have been developed to function as a "top assembly drawing" for each board. These pages identify the component locations on the board and provides links to the files needed for board manufacture and assembly. A brief description of the function of each board is provided at the top its top assembly drawing page.

View the Strobe Control Board Top Assembly PDP

View the DDS Clocks Board Top Assembly PDP

NOTE: The Top Assembly Drawing pages may be revised in response to comments received.

Go to the Bid page, or

Go to the Comment Form page, or

Up to National Advanced Manufacturing Testbed page.

NOTICE: These pages are experimental

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CHP: HTML- 1/28/99, rev 2/18/99

Strobe Control Board

NIST Part#: 122898-A

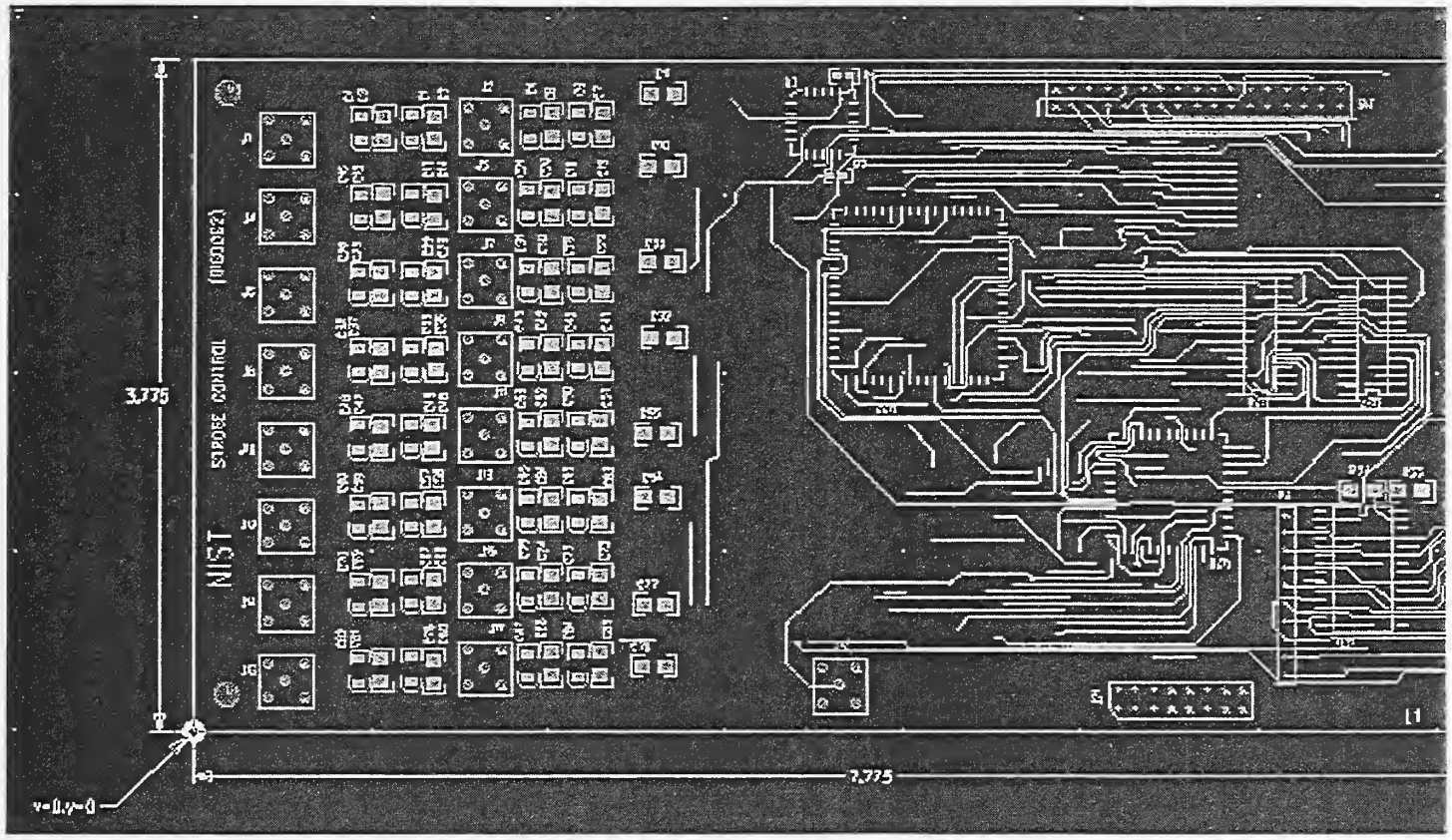
NOTICE: Experimental - the Disclaimer on the Product Data Package page applies.

Manufacturability Testing: completed; ADI Test Report is available.

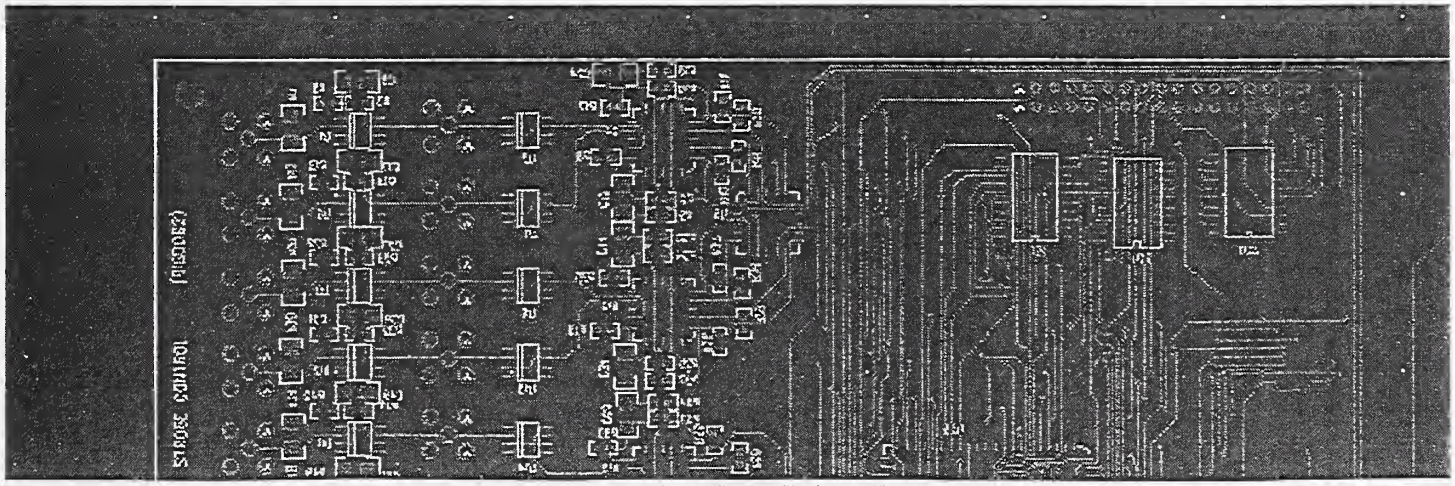
Revision History: ECO 001 incorporated (updated files listed as -1)

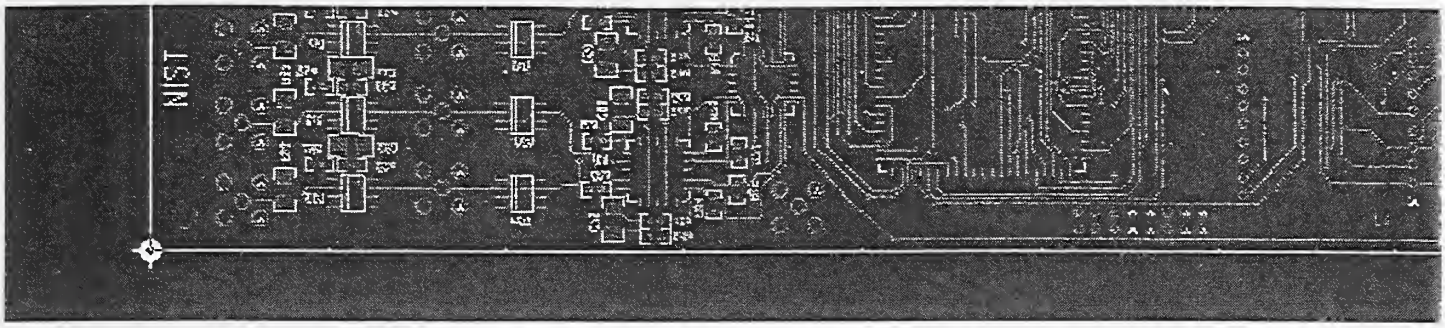
A functional description strbctl page is available for this PCA.

Top Assembly View; see also Top Parts Placement View PDF file



Bottom Assembly View; see also Bottom Parts Placement View PDF file





CAD File

The ASCII CAD export -1 file (size=360K) is available.

Bill of Materials and Net List

AVL NOTE: All parts are listed with generic part number; vendor is optional

- BOM, in HTML: BOM.html

- BOM, in Excel: strb_ctl.xls)

Netlist: STRB_CTL.NET

Build Specifications

OEM Technical Contact: Robert.Palm@eeel.nist.gov; please contact by e-mail with cc to icm@eeel.nist.gov

- Board finished size: 3.775 X 7.775 inches

NOTE: Targets to be added by board manufacturer; no fiducials are on artwork.

- Material: FR4, .062" final thickness.

- Finish: Solder mask over bare copper.

- Solder Mask: liquid photo imageable mask.

- Silk Screen: white.

- Build to IPC-A-600 and Best Commercial Practices.

PCB Build Files (links provided for each file)

- Aperture Dcodes: aperture.rep text file.

- Layer 1 Gerber: art01.pho -1 text file.

- Layer 2 Gerber: pgp02.pho -1 text file.

- Layer 3 Gerber: pgp03.pho -1 text file.

- Layer 4 Gerber: art04.pho -1 text file.

- Silk Screen, Top: sst0126.pho -1 text file.

- Silk Screen - Bottom: sst0429.pho -1 text file.

- Solder Mask - Top: sm0121.pho -1 text file.

- Solder Mask - Bottom: sm0428.pho -1 text file.

- Excellon Drill Size table: drl01.rep -1 text file.

- Excellon Drill Schedule: drl01.drl -1 text file.

- Drill Schedule: drl01.lst -1 text file.

CAM; Assembly Machine Files (Others available; contact Robert Palm)

- Quad 00, Top: QUADST.100 text file.

- Quad 00, Bottom: QUADSB.100 text file.

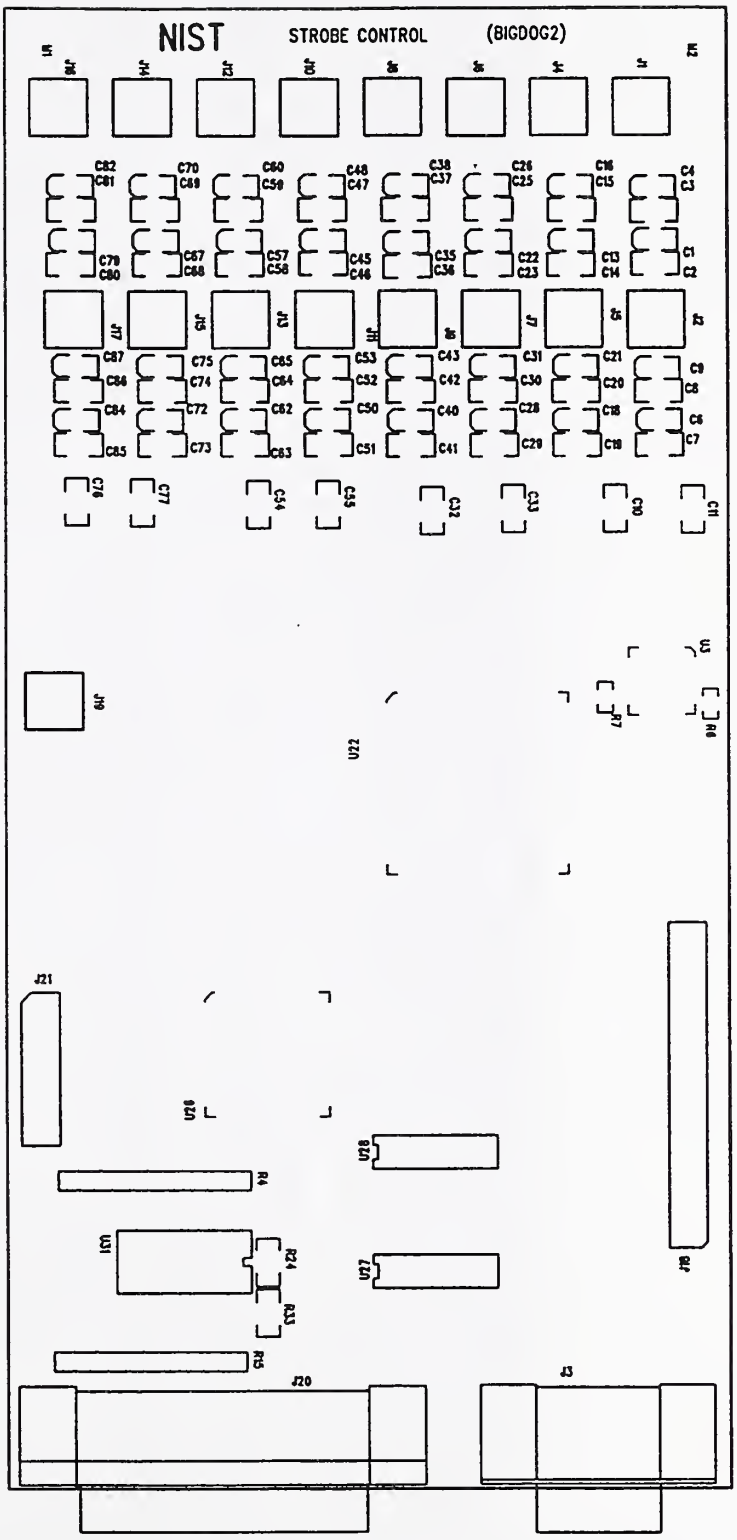
- Universal 6772, Top: (please request if needed).

- Universal 6772, Bottom: (please request if needed).

- Zevatech Ppm-9, Top: ZEVAST.PPM text file.

- Zevatech Ppm-9, Bottom: ZEVASB.PPM text file.

Return to Product Data Package page.


NIST
STROBE CONTROL
(BIGDOG2)
J21
J20
J3
J8

Bill of Materials for STRB_CTL PCA

Qty	Reference	Part Name	Value	Manufacturer	Part Number
1	C1	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C2	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C3	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C4	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C5	CC1206	10 pF, 50 V	Panasonic or equivalent	ECU-V1H100DCM
1	C6	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C7	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C8	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C9	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C10	CC1206	.1uF, 16V	Panasonic or equivalent	ECJ-3VB1C104K
1	C11	CC1206	.1uF, 16V	Panasonic or equivalent	ECJ-3VB1C104K
1	C12	CC1206	120pF, 50V	Panasonic or equivalent	ECU-V1H121JCH
1	C13	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C14	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C15	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C16	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C17	CC1206	10 pF, 50 V	Panasonic or equivalent	ECU-V1H100DCM
1	C18	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C19	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C20	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C21	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C22	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C23	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C24	CC1206	120pF, 50V	Panasonic or equivalent	ECU-V1H121JCH
1	C25	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C26	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C27	CC1206	10 pF, 50 V	Panasonic or equivalent	ECU-V1H100DCM
1	C28	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C29	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C30	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C31	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C32	CC1206	.1uF, 16V	Panasonic or equivalent	ECJ-3VB1C104K
1	C33	CC1206	.1uF, 16V	Panasonic or equivalent	ECJ-3VB1C104K
1	C34	CC1206	120pF, 50V	Panasonic or equivalent	ECU-V1H121JCH
1	C35	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C36	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C37	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C38	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C39	CC1206	10 pF, 50 V	Panasonic or equivalent	ECU-V1H100DCM
1	C40	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C41	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C42	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C43	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C44	CC1206	120pF, 50V	Panasonic or equivalent	ECU-V1H121JCH
1	C45	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C46	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C47	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM

1	C48	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C49	CC1206	10 pF, 50 V	Panasonic or equivalent	ECU-V1H100DCM
1	C50	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C51	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C52	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C53	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C54	CC1206	.1uF, 16V	Panasonic or equivalent	ECJ-3VB1C104K
1	C55	CC1206	.1uF, 16V	Panasonic or equivalent	ECJ-3VB1C104K
1	C56	CC1206	120pF, 50V	Panasonic or equivalent	ECU-V1H121JCH
1	C57	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C58	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C59	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C60	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C61	CC1206	10 pF, 50 V	Panasonic or equivalent	ECU-V1H100DCM
1	C62	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C63	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C64	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C65	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C66	CC1206	120pF, 50V	Panasonic or equivalent	ECU-V1H121JCH
1	C67	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C68	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C69	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C70	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C71	CC1206	10 pF, 50 V	Panasonic or equivalent	ECU-V1H100DCM
1	C72	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C73	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C74	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C75	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C76	CC1206	.1uF, 16V	Panasonic or equivalent	ECJ-3VB1C104K
1	C77	CC1206	.1uF, 16V	Panasonic or equivalent	ECJ-3VB1C104K
1	C78	CC1206	120pF, 50V	Panasonic or equivalent	ECU-V1H121JCH
1	C79	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C80	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C81	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C82	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C83	CC1206	10 pF, 50 V	Panasonic or equivalent	ECU-V1H100DCM
1	C84	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C85	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C86	CC1206	2000 pF, 50 V	Panasonic or equivalent	ECU-V1H222KBM
1	C87	TANTCHIP1206	.47uF, 25V	Panasonic or equivalent	ECS-T1EY474R
1	C88	CC1206	120pF, 50V	Panasonic or equivalent	ECU-V1H121JCH
1	J1			Johnson	142-0701-201
1	J2			Johnson	142-0701-201
1	J3			AMP	745781-4
1	J4			Johnson	142-0701-201
1	J5			Johnson	142-0701-201
1	J6			Johnson	142-0701-201
1	J7			Johnson	142-0701-201
1	J8			Johnson	142-0701-201

1	J9			Johnson	142-0701-201
1	J10			Johnson	142-0701-201
1	J11			Johnson	142-0701-201
1	J12			Johnson	142-0701-201
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1	J15			Johnson	142-0701-201
1	J16			Johnson	142-0701-201
1	J17			Johnson	142-0701-201
1	J18	HEADER34		Sullins or equivalent	PZC36DAAN
1	J19			Johnson	142-0701-201
1	J20			AMP	745783-4
1	J21	HEADER16		Sullins or equivalent	PZC36DAAN
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1	R2	CR1206	510	Panasonic or equivalent	ERJ-8GEY511
1	R3	CR1206	1k	Panasonic or equivalent	ERJ-8GEY102
1	R4	710A	470	Bourns	81f9205R470
1	R5	CR1206	4.7k	Panasonic or equivalent	ERJ-8GEY472
1	R6	CR1206	470	Panasonic or equivalent	ERJ-8GEY471
1	R7	CR1206	470	Panasonic or equivalent	ERJ-8GEY471
1	R8	CR1206	200	Panasonic or equivalent	ERJ-8GEY201
1	R9	CR1206	330	Panasonic or equivalent	ERJ-8GEY331
1	R10	CR1206	470	Panasonic or equivalent	ERJ-8GEY471
1	R11	CR1206	470	Panasonic or equivalent	ERJ-8GEY471
1	R12	CR1206	51	Panasonic or equivalent	ERJ-8GEY510
1	R13	CR1206	510	Panasonic or equivalent	ERJ-8GEY511
1	R14	CR1206	1k	Panasonic or equivalent	ERJ-8GEY102
1	R15	710A	470	Bourns	4610X-101-470
1	R16	CR1206	4.7k	Panasonic or equivalent	ERJ-8GEY472
1	R17	CR1206	200	Panasonic or equivalent	ERJ-8GEY201
1	R18	CR1206	330	Panasonic or equivalent	ERJ-8GEY331
1	R19	CR1206	470	Panasonic or equivalent	ERJ-8GEY471
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1	R21	CR1206	51	Panasonic or equivalent	ERJ-8GEY510
1	R22	CR1206	510	Panasonic or equivalent	ERJ-8GEY511
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1	R31	CR1206	510	Panasonic or equivalent	ERJ-8GEY511
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1	R33	CR1206	1k	Panasonic or equivalent	ERJ-8GEY102
1	R34	CR1206	4.7k	Panasonic or equivalent	ERJ-8GEY472
1	R35	CR1206	200	Panasonic or equivalent	ERJ-8GEY201

1	R36	CR1206	330	Panasonic or equivalent	ERJ-8GEY331
1	R37	CR1206	470	Panasonic or equivalent	ERJ-8GEY471
1	R38	CR1206	470	Panasonic or equivalent	ERJ-8GEY471
1	R39	CR1206	51	Panasonic or equivalent	ERJ-8GEY510
1	R40	CR1206	510	Panasonic or equivalent	ERJ-8GEY511
1	R41	CR1206	1k	Panasonic or equivalent	ERJ-8GEY102
1	R43	CR1206	4.7k	Panasonic or equivalent	ERJ-8GEY472
1	R44	CR1206	200	Panasonic or equivalent	ERJ-8GEY201
1	R45	CR1206	330	Panasonic or equivalent	ERJ-8GEY331
1	R46	CR1206	470	Panasonic or equivalent	ERJ-8GEY471
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1	R68	CR1206	1k	Panasonic or equivalent	ERJ-8GEY102
1	R70	CR1206	4.7k	Panasonic or equivalent	ERJ-8GEY472
1	R71	CR1206	200	Panasonic or equivalent	ERJ-8GEY201
1	R72	CR1206	330	Panasonic or equivalent	ERJ-8GEY331
1	R73	CR1206	470	Panasonic or equivalent	ERJ-8GEY471
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1	U2			Burr-Brown Corp	OPA655U
1	U3			Motorola	MC10H103FN
1	U4			Analog Devices	AD96687BR
1	U5			Motorola	MC10H125-FN
1	U6			Burr-Brown Corp	OPA655U
1	U7			Burr-Brown Corp	OPA655U
1	U8			Burr-Brown Corp	OPA655U
1	U9			Burr-Brown Corp	OPA655U
1	U10			Analog Devices	AD96687BR
1	U11			Burr-Brown Corp	OPA655U
1	U12			Burr-Brown Corp	OPA655U
1	U13			Burr-Brown Corp	OPA655U

1	U14			Burr-Brown Corp	OPA655U
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1	U16			Motorola	MC10H125-FN
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1	U18			Burr-Brown Corp	OPA655U
1	U19			Burr-Brown Corp	OPA655U
1	U20			Burr-Brown Corp	OPA655U
1	U21			Analog Devices	AD96687BR
1	U22 *			Advnace Mirowave Devices	MACH220-20JC
1	U23			Burr-Brown Corp	OPA655U
1	U24			Burr-Brown Corp	OPA655U
1	U25 *			Advnace Mirowave Devices	MACH435-15JC
1	U26 *			Advnace Mirowave Devices	MACH215-12JC
1	U27			Toshiba	TC5588J20
1	U28			Toshiba	TC5588J20
1	U29			TI or Motorola	SN74LS245DW
1	U30			TI or Motorola	SN74LS245DW
1	U31			Motorola	MC10E111FN
1	U32			TI or Motorola	SN74LS245DW
		*		To be programmed at NIST	

Last Updated on 2/19/99
By Robert H. Palm, Jr.

Appendix C

The following pages have been printed from a Web browser.

Engineering Change Order 001; 2 pages [Reference: http://www.eeel.nist.gov/~parks/icm/pcafiles/strb_ctrl/eco1.html, 17 February 1999.]

> This HTML page contains most of the information found in a Engineering Change Order (ECO) which identifies the changes incorporated in a specified revision of the Strobe Control Board.

Engineering Change Order 001

Status: APPROVED

Effectivity

Part 122898, units 1 and on

Reason for ECO

Eliminate short between power nets in artwork.

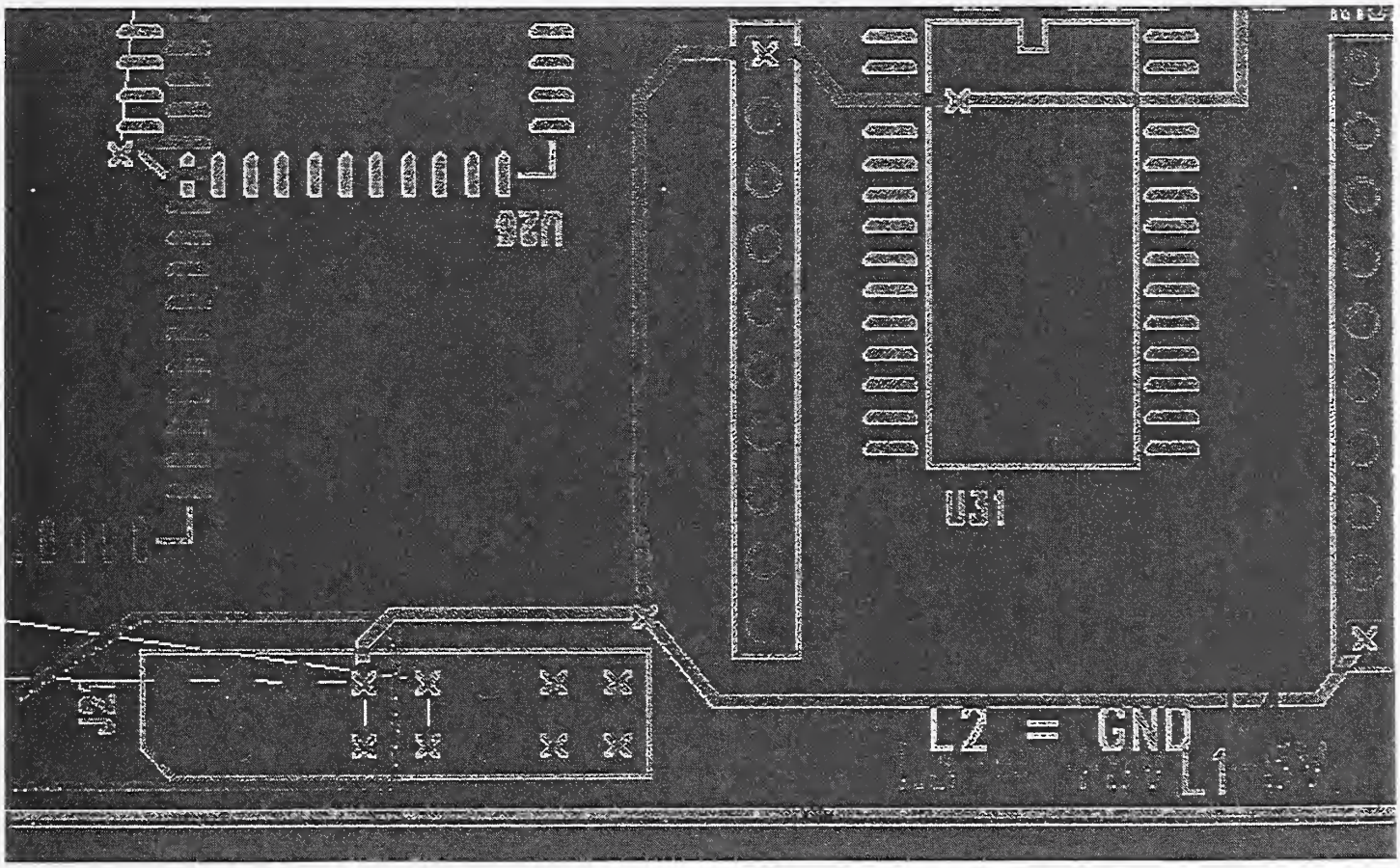
Files incorporating change

All Gerber and Drill files

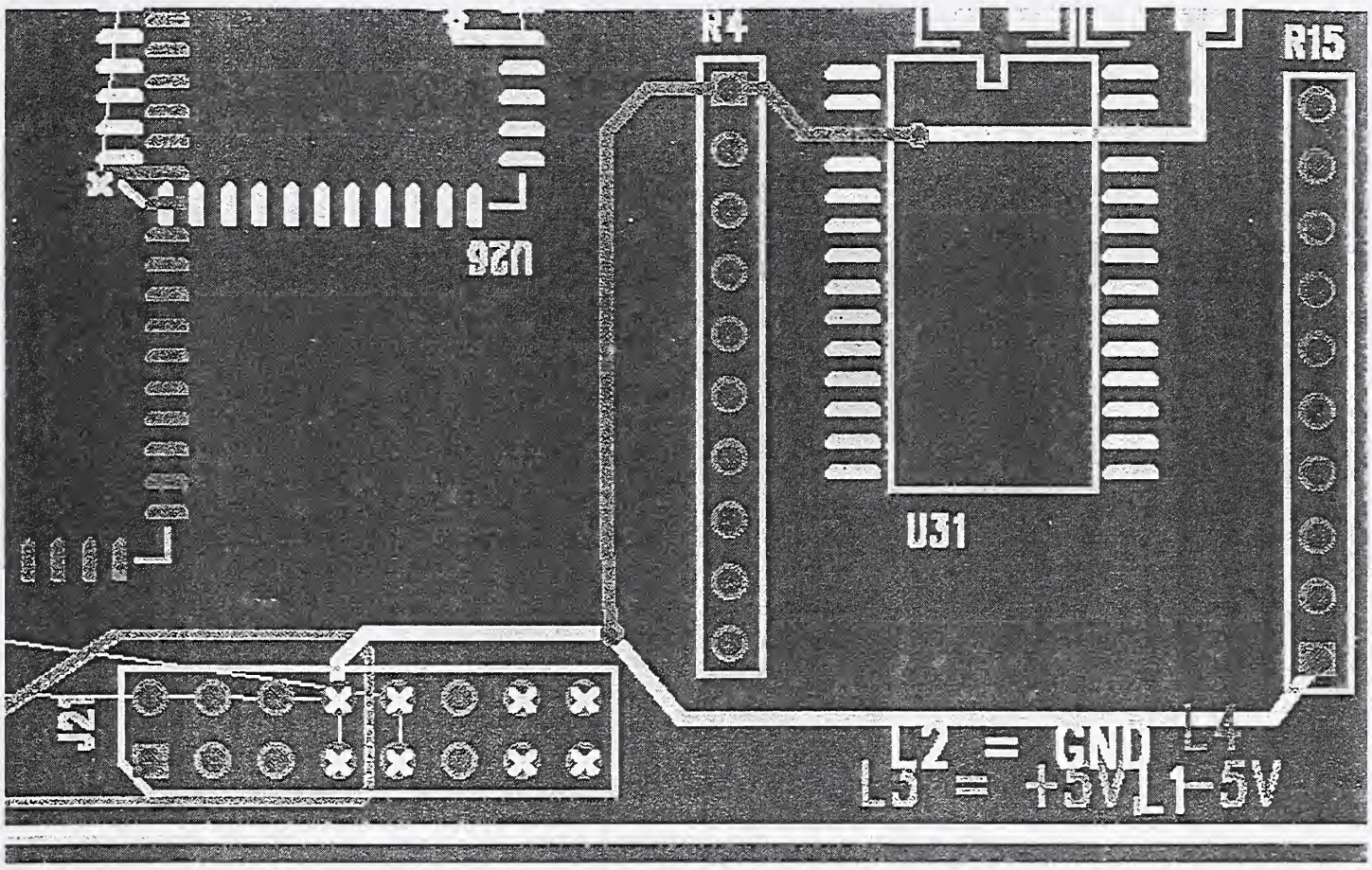
Applicable Artwork Images

Image colors used:
- Top Silk Screen = green
- Layer 1 Artwork = blue
- Layer 2 Artwork = yellow
- Layer 3 Artwork = olive
- Layer 4 Artwork = red

Was (previous) CAD Image



Is (corrected) CAD Image



ECO: R. Palm 2/12/99
HTML: C. Parks 2/17/99